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LANDSAT Follow-on Investigation #22510  
Type II Progress Report #6  
Three Months Ending 1 September 1976

## The Use of LANDSAT DCS and Imagery in Reservoir Management and Operation

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(E77-10049) THE USE OF LANDSAT DCS AND  
IMAGERY IN RESERVOIR MANAGEMENT AND  
OPERATION Progress Report, period ending 1  
Sep. 1976 (Corps of Engineers, Waltham,  
Mass.) 13 p HC A02/MF A01 CACL 08H G3/43

### 1. ACCOMPLISHMENTS

a. DCS - NED's LANDSAT downlink has been fully imple-  
mented and the tracking system operates unattended with near  
100 percent reliability. Software has been developed with the  
intention of the recovery from various malfunctions. Power  
interruptions do not abort the data collection function entirely,  
but if a satellite pass is in progress when a power failure  
occurs, the remainder of data from the current pass will be  
lost; however, the computer will recoup by the next pass.

The LANDSAT tracking system integrates a set of about 20  
programs or subroutines, about 10 disc data files and several  
pieces of equipment. The hardware configuration is shown in  
Figure 3, and the interrelationship of the programs and data  
files is shown in Figure 4. Essentially, the system predicts  
the satellite position, tracks the satellite, stores the incoming  
data, returns to the predicting program, and continues cycling  
in that fashion. In addition, the minicomputer controlling this  
operation can be made to concurrently drive a separate oper-  
ational data collection network, NED's Automatic Hydrologic  
Radio Reporting Network, a land-based system that has been in  
operation for six years.

Location of NED's Data Collection Platforms (DCP's) is  
shown on Figure 5. At present 18 General Electric DCP's are  
installed in the field, three others require service, and eight

are on hand as spares or are to be placed in the field shortly.

NED owns two LaBarge Convertible DCP's. The first, I.D. 7101, has been set up as a demonstration in our computer room and is transmitting data from a precipitation gage. The other LaBarge unit has been returned to the manufacturer for checkout of unusually high power consumption.

We will be installing two snow pillows in remote sites on the Saint John and Allagash Rivers in northern Maine. One will also be installed at Waltham for close observation during the winter of 1976-77.

A thermocouple interface to a LANDSAT DCP is being completed during this quarter for placement at Sugarloaf Mountain, Maine. The field installation will be accomplished by September.

#### b. Imagery

(1) Computer Analysis - The display shown in Figure 1 shows an example of the computer processing using the LANDSAT computer compatible taped (CCT's). The upper half of the display is a printout of MSS band 5 energy values. The energy or differing radiance levels contained within a LANDSAT scene are registered on a scale from 0 to 127 (minimum to maximum values) for MSS bands 4, 5 and 6; however, on MSS band 7 the scale is 0 to 63 (minimum to maximum values). Since the computer keyboard used in this study does not contain 128 different characters, the computer algorithm groups the energy values into a 3-step increment using first the letters A-Z, second the numbers 1-0, and last the other symbols, such as: /, ' " = + ( ) \* & % \$ @ +. For example, the letter A represents energy values of 0-2, the letter E represents energy values from 12-14, and so on through the alphabet, numbers and symbols.

Initial analysis of the four MSS energy band computer printouts showed that the greatest contrast between the areas of snow on open spaces, such as rivers and fields, and forested areas occurred on MSS band 5 (0.6-0.7 micrometers). This contrast was also visually observed on the 9x9 inch black and white print of the 19 April 1974 LANDSAT scene (ID 1635-14541). Figure 1 (upper part) is an example of MSS band 5 energy values and shows the confluence of the Saint John and Allagash Rivers.

The confluence is evident due to the contrast between the snow covered rivers and the surrounding forested land. Each symbol on the display (Figure 1) represents a "pixel" or picture element that is 57x79 meters or 1.1 acres. Points of high contrast are selected for location purposes on the CCT's.

Two test sites were then selected from the MSS band 5 printout to develop training sets that could be used to relate radiance values to types of snow (Test Sites A and B). The computer tapes of all four MSS bands were used in this analysis. Test Site A was selected primarily because there was no available ground truth, but the elevation, slope and aspect at this site are known. Test Site B contained a snow course (#140) operated by the U.S. Geological Survey. Each test area is composed of a 41x30 pixel array.

The classification of the pixels on all four MSS bands into basically two land cover types - snow covered water and the forested land - was accomplished by applying a discriminant value determined by a trial and error method to the computer algorithm. The 4-band observations on each pixel in the test site can be considered as a vector representation in a 4-wave-length space, whose directions determine gross color (the MSS bands 4, 5, 6 and 7 "colors") and whose magnitudes relate to intensity, brightness or the energy values for each MSS band (Pers. comm., Dr. Stephen Ungar, GISS, New York, N. Y.).

The discriminant value used for Test Site B' did separate the snow covered river from the forested land. The two major classification units in Test Site B' were the land unit (/) having a snow radiance of 2.8 and a snow covered water unit (\*) having a radiance of 7.62. However, in Test Site A', when the same discriminant was used, all the pixels were classified into one major unit (/), which had an average snow radiance value of 4.80. In this test site area, there was probably not a high contrast between the land and the snow covered water, as was the case in Test Site B'. In fact, there was probably a very high total radiance across Test Site A' as the snow value of 4.80 falls approximately midway between the two land cover values recorded for Test B' - 2.80 and 7.62.

The diagonal symbols (/) for Test Sites A' and B' were re-defined into 10 discrete land use types to further separate the

snow covered area. In Test Sites A" and B" these 10 classification units are represented by number symbols, 1 through 0, or by colors (Table 1).

TABLE 1  
SNOW ALBEDO VALUES

<u>Symbol</u>	<u>Color</u>	<u>Test Site A</u>	<u>Test Site B</u>
/		4.80	2.80
*		4.45	7.62
.			5.35
+			6.47
Q			4.44
W			6.64
1	Bright Green	2.60	2.25
2	Medium Green	3.18	2.50
3	Dark Green	3.82	2.72
4	Blue	4.31	2.96
5	Red	4.85	3.19
6	Purple	5.50	3.41
7	Gray-Brown	5.91	3.67
8	Brown	6.37	3.85
9	Orange	6.74	4.11
0	Yellow	7.34	4.34

The 10 land cover units in Test Site B" ranged in snow radiance values from 2.25 to 4.34 and were redefined from the "/" symbol of 2.80 shown on the Test Site B' map. The "/" category could have been broken into fewer than 10 classification units (for example 5), which might have indicated a better correlation of snow radiance values to moisture content. Refinement of this procedure is continuing.

Test A" was separated into 10 land cover units ranging in snow radiance values from 2.60 to 7.34. In the Test A" map, the snow covered water and land were separated. However, it is noticed that the "/" symbol is still evident throughout the Test

Site A' map. The snow radiance values were so large in the " " symbols that they lie outside the originally defined vector cluster the Test Site A' " " and were not considered in this 10-part classification scheme. The original vector cluster of " " from Test Site A' is defined from a 2-vector component cluster. In this case, a smaller discriminant will be required to isolate the high radiance " " in Test Site A' from the average (4.80 value) cluster. Refinement of the discriminant for Test Site A' is continuing to better define the snow and land boundary.

This technique is being used to define snow radiance values for the Saint John River watershed. Selected test sites on the CCT's based on ground truth (snow course data) and without ground truth (slope, elevation and aspect) are being analyzed.

(2) Computer Equipment - A Tektronix 4013 CRT (cathode ray tube) display unit was obtained by CRREL in July 1976. This unit can be used on the NASA GISS (Goddard Institute for Space Studies) computer system and allows interaction with the computer for imagery analysis of the CCT's.

## 2. MAJOR PROBLEMS

a. DCS - There are no unresolved problems in our Data Collection System at this time. Repairs were made on the NED downlink during this reporting period at a cost of \$850. Most of the malfunctions were in Scientific-Atlanta Pedestal Control Equipment, and a large proportion of the cost was for labor.

b. Imagery - The GISS/CRREL computer data line has not been working properly; however, steps will be taken to obtain a direct phone line to the system. In addition, the 2000 baud modem is being replaced by a 2400 baud modem.

## 3. SIGNIFICANT RESULTS

a. DCS - A graph that shows the snow water equivalent data during the 1975-76 winter season for the Ninemile and Michaud Farms snow pillows located in northern Maine is shown in Figure 2. The Bourne transducers used in the snow pillow interface were tested after field use under controlled laboratory conditions of temperature and pressure. It was found that the temperature calibration curve for the Bourne transducers became

erratic below 0° Centigrade. Results obtained from a CRREL in-house study on the reliability of a number of transducers has indicated that the Bourne transducers should be replaced by Endevco transducers in the snow pillow interface. This new system will be used during the 1976-77 winter season.

On 8-10 August 1976, the remainder of hurricane "Belle" travelled through Vermont, New Hampshire, northern Maine, and on into Canada's Maritime Provinces dumping 3 inches of rain in many areas. In Canada and Maine local storms dropped up to 2 inches during the following week. The Saint John River reached near flood stages at Fort Kent, Maine. During this storm DCP data was being received from Fort Kent (DCP #7171), from Ninemile Bridge (DCP #7273), and from the Saint Francis River in New Brunswick (DCP #6504, belonging to the Department of the Environment, Ottawa, Ontario, Canada).

The resulting high runoff after these storms was studied in connection with the proposed Dickey-Lincoln School dams to be built in that area, and significantly, it was found that creditable flood hydrographs could be generated from LANDSAT DCP data in spite of the voids caused by the satellite being below the horizon.

In the aftermath of these storms hydrologic data was exchanged between the New England Division and the Saint John (New Brunswick) Power Commission River Forecast Center. This exchange is a continuation of a mutually beneficial relationship started two years ago.

b. Imagery - Analysis of computer compatible tapes is continuing as explained in Section 1, and significant results are not yet available.

#### 4. MEETING AND VISITORS

a. DCS - A meeting was held at Sugarloaf Mountain, Kingfield, Maine on 24 June 1976. The participants included Dr. Harlan McKim and Ms. Carolyn Merry (CRREL), Messrs. Saul Cooper and Paul Hetu (NED), Dr. Harold Borns (University of Maine), and Mr. Hazen McMullen (Vice-President of Sugarloaf Corporation). The purpose of the meeting was to discuss the location for the placement of a thermocouple chain interfaced

to the LANDSAT data collection system. The field site is located on top of Sugarloaf Mountain (elevation 4237 feet). The primary objective is to test the reliability of the thermocouple interface during extreme winter weather conditons. The secondary objective is to monitor the ground temperature to a depth of 100 feet to determine if freezing temperatures can occur year round at this latitude.

On 30 August 1976, a briefing was given the newly appointed Chief of Engineers, Lieutenant General John W. Morris. A copy of the briefing sheet presented to him before his visit is attached. The last two paragraphs of the sheet are indicative of NED's attitude toward satellite data collection and represent the message we are trying to promote at every opportunity.

Shortly after the inspection by Lieutenant General Morris, we were visited by Mr. William Taylor, Chief of R&D at OCE, and Colonel Maurice K. Kurtz, Jr., Commander and Director of Engineer Topographic Laboratories, Fort Belvoir, Virginia. Discussions with Messrs. Saul Cooper and Timothy Buckelew afforded an exchange of technology and another opportunity to recommend that the Corps support satellite data collection.

## 5. RECOMMENDATIONS

None

## 6. FUTURE PLANS

a. DCS - During the remainder of the investigation we will explore the economics of satellite data collection and compare various alternatives.

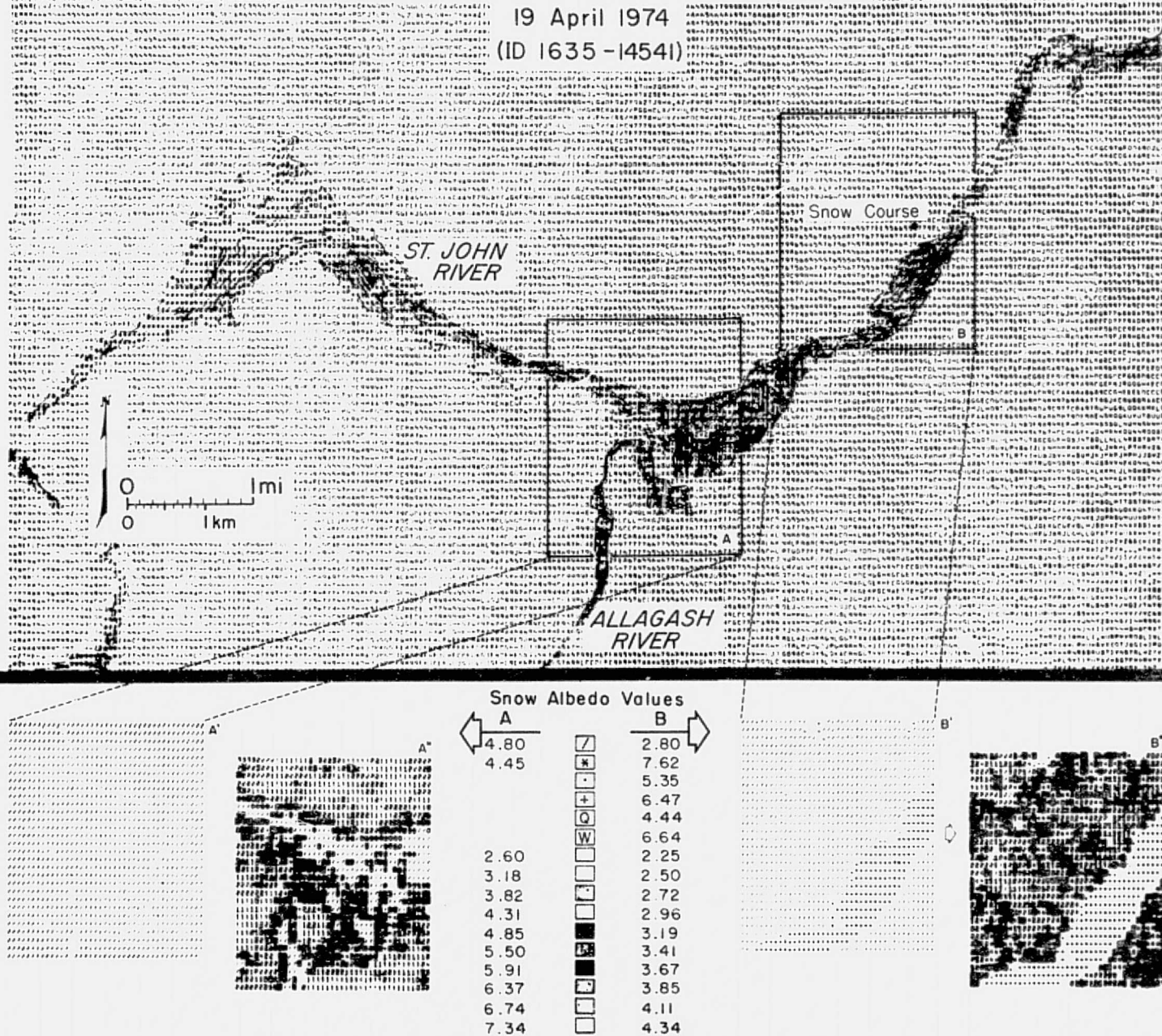
b. Imagery - The LANDSAT imagery analysis will continue in the development of snow radiance values for selected snow course locations and test sites. The snow radiance values obtained for various snow depths and snow water content will be developed as training signatures. The training signatures will be applied to the upper Saint John River basin to predict the moisture equivalency of the snowpack. Moisture equivalency and snow course data will be used to estimate the total runoff in the watershed.



# LANDSAT - IMAGERY ANALYSIS

19 April 1974  
(ID 1635 - 1454)

Figure 1. Computer processing being accomplished using LANDSAT CCT's.



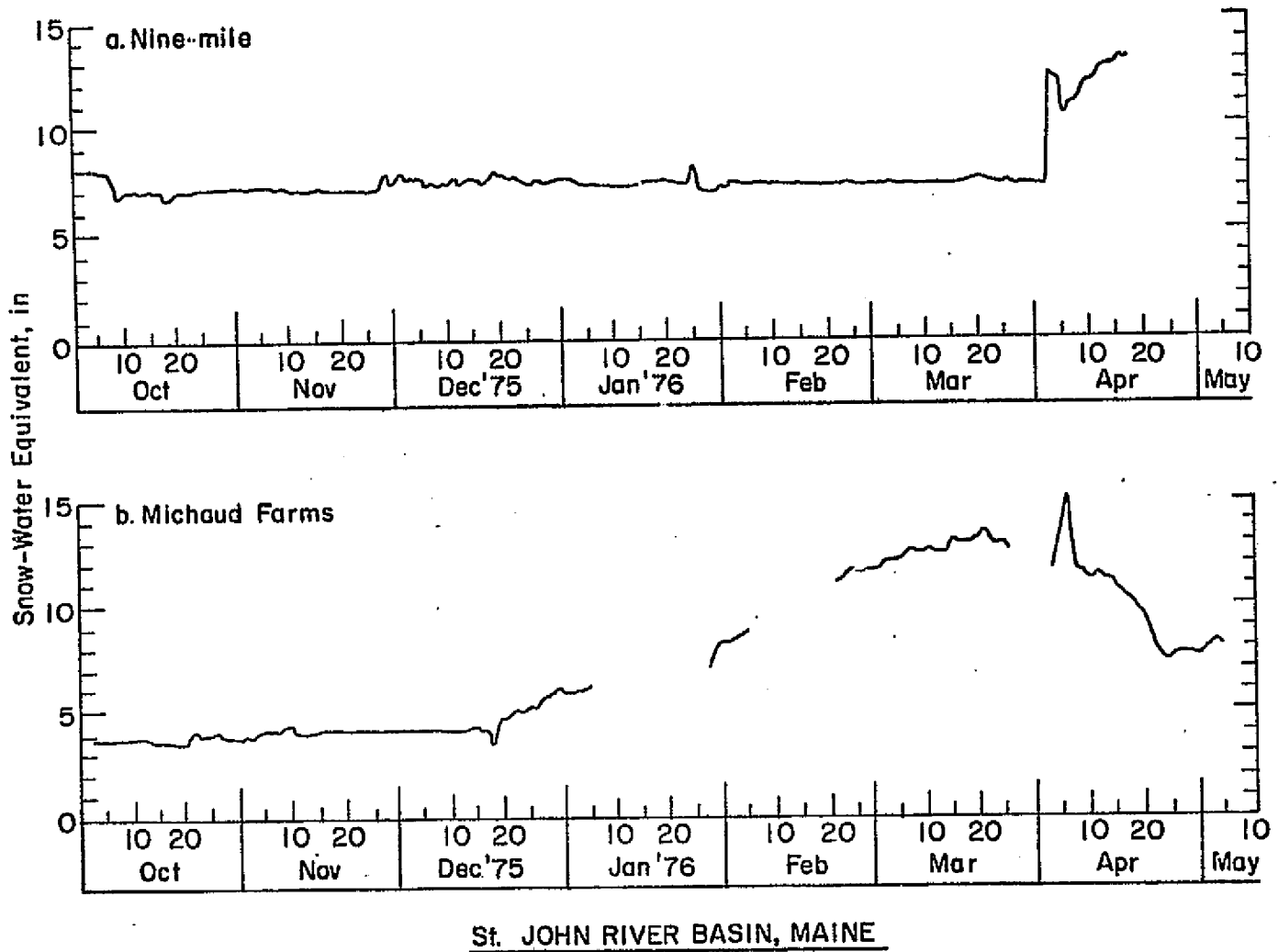
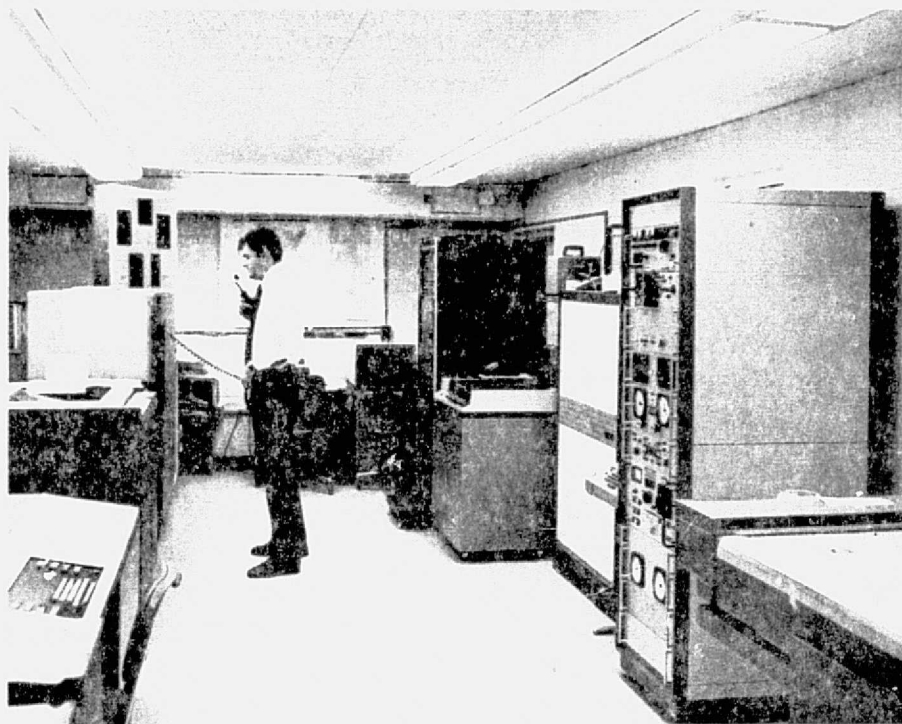
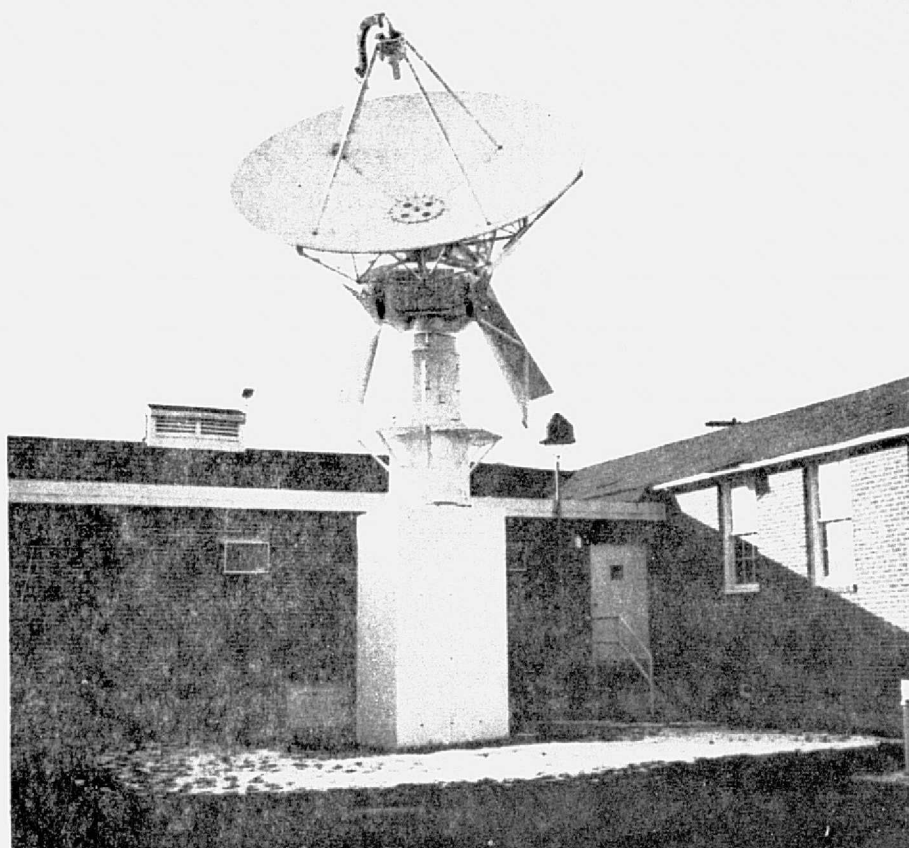


Figure 2. Snow water equivalent data during 1975-76 winter season for the Nine-Mile and Michaud Farms snow pillows in northern Maine.

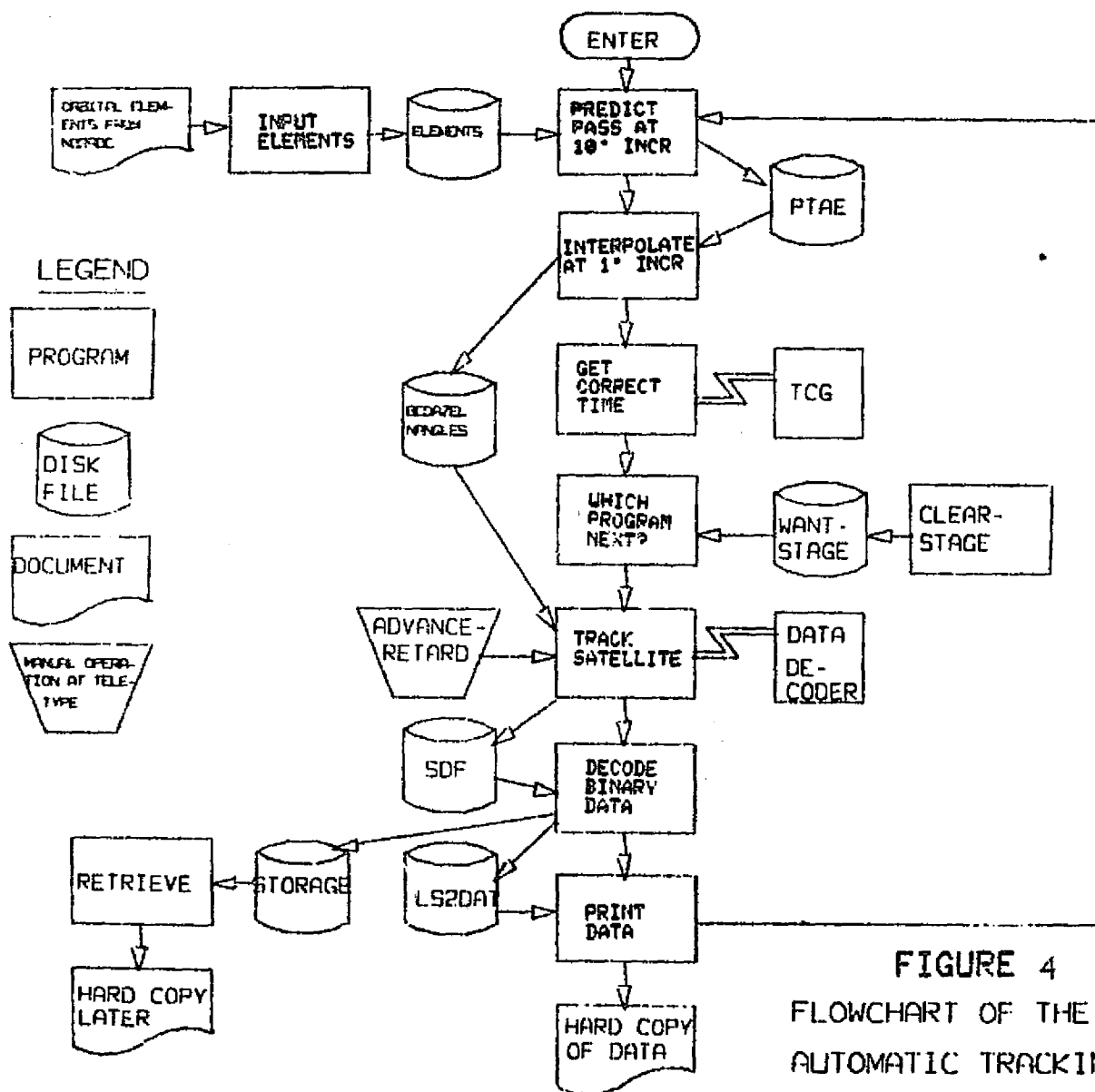
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**COMPUTER ROOM**



**15 FT. RECEIVING ANTENNA**



**FIGURE 4**  
FLOWCHART OF THE LANDSAT  
AUTOMATIC TRACKING SYSTEM

# FIGURE 5

LANDSAT-2 - DCP INFORMATION SHEET  
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION 9 NOVEMBER 1976

DCP NO.	STATION NAME	PARA-METER(S)*	LAT	LONG
7171	ST. JOHN RIVER AT NINEMILE BRIDGE, ME.	RS WES	46 42 00	69 42 59
7273	ST. JOHN RIVER AT FORT KENT, ME.	RS	47 15 27	68 35 35
7147	MICHAUD FARM AT ALLAGASH FALLS, ME.	WES	45 57 05	69 11 43
7071	PENOBSCOT RIVER AT WEST ENFIELD, ME.	RS	45 14 12	68 38 56
7272	CARABASSETT RIVER NEAR NORTH ANSON, ME.	RS	44 52 09	69 57 20
7356	SACO RIVER AT CORNISH, ME.	RS	43 48 35	70 46 53
7127	SOUTH MOUNTAIN, N.H.	P	42 58 59	71 35 21
7201	PEMIGEWASSET RIVER AT PLYMOUTH, N.H.	RS	43 45 33	71 41 10
7207	MERRIMACK RIVER NEAR GOFFS FALLS, N.H.	RS	42 56 54	71 27 52
7246	WACHUSETT MOUNTAIN, MA.	P	42 29 24	71 53 15
6063	IPSWICH RIVER NEAR IPSWICH, MA. (1)	RS	42 39 35	70 53 39
7271	NORTH NASHUA RIVER AT FITCHBURG, MA.	RS	42 34 34	71 47 19
7142	CHICOPEE RIVER AT CHICOPEE FALLS, MA.	WQ	42 09 37	72 34 52
7021	WESTFIELD RIVER AT WEST SPRINGFIELD, MA.	WQ	42 05 59	72 38 28
7107	NED, WALTHAM, MA. (LABARGE)	P	42 23 46	71 12 56
7220	BRANCH RIVER AT FORESTDALE, R.I.	RS	41 59 47	71 33 47
7345	PAWUXET RIVER AT CRANSTON, R.I.	RS	41 45 03	71 26 44
7254	CONNECTICUT RIVER AT HARTFORD, CT.	RS	41 46 10	72 40 04
7242	CONNECTICUT RIVER NEAR MIDDLETOWN, CT.	RS	41 33 40	72 36 45
7206	PORTER BROOK NEAR MANCHESTER, CT. (2)	RS	41 45 55	72 30 12
7214, 6216, 7042 (3)	PL, AT, GST, GT, UP			
7103-7105, 7110-7120	ASSIGNED TO CRREL'S C/DCP'S			
7304, 7012, 7233, 7355, 7106, 7335, 7010, 7325	SPARES			

\* P - PRECIPITATION AT - AIR TEMPERATURE(S)  
WES - WATER EQUIVALENT OF SNOWPACK GST - GROUND SURFACE TEMPERATURE  
RS - RIVER STAGE GT - GROUND TEMPERATURE(S)  
RL - RESERVOIR LEVEL WQ - WATER QUALITY  
WQ - WATER QUALITY (TEMPERATURE, CONDUCTIVITY, PH AND DISSOLVED OXYGEN) PU - PARAMETERS VARIABLE  
T - TEST SET

- (1) DCP OPERATED BY U.S. GEOLOGICAL SURVEY, BOSTON, MA.
- (2) DCP ON LOAN TO U.S. GEOLOGICAL SURVEY, HARTFORD, CT. - ON DEMONSTRATION AT THE MANCHESTER NATURE CENTER
- (3) DCP ON LOAN TO U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LAB, HANOVER, N.H.
- (4) NOT YET INSTALLED

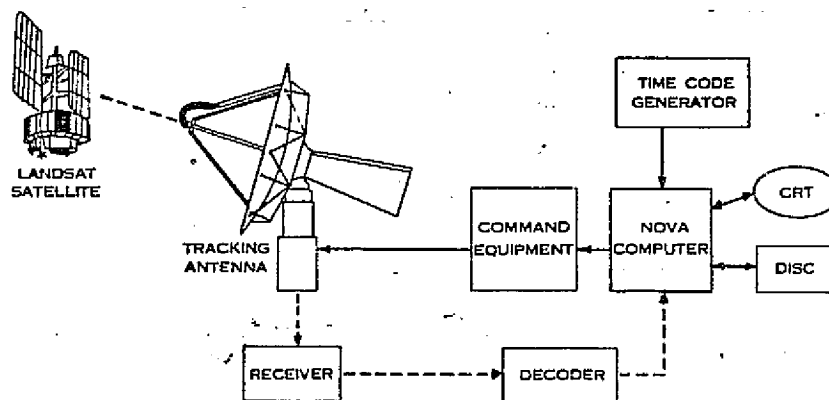
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## New England Division, Corps of Engineers

### SUBJECT: NASA-LANDSAT Experiment

1. Background and Information. In June 1972, NASA entered into a contract with the NED for an experiment to study the feasibility of using the Earth Resources Technology Satellite (ERTS or LANDSAT) for collecting environmental data. NED was selected because of its experience in operating a real time hydrologic radio reporting network which was installed in 1970.

2. Status. Under this program over 25 Data Collection Platforms (DCP's) have been installed at locations throughout New England. Since July 1972, LANDSAT has been relaying river stage, precipitation and water quality data from DCP's via the Goddard Space Flight Center to the U.S. Army Corps of Engineers, New England Division, in near real time.



### THE NED GROUND RECEIVE STATION

NED recommended that any operational satellite configuration should include ground receiving stations at all major user locales. With NASA support, NED has constructed and is now operating an inexpensive semiautomatic and easily maintained ground receive station as a follow-up to its original study. The Division is now able to receive hydrometeorological data from data collection platforms in the field directly at its headquarters in Waltham, Massachusetts, with no time delays.

3. Comments. A major objective of the program has been to compare the cost, reliability, and operational effectiveness of the LANDSAT Data Collection System with the existing NED radio network. Also, through our association with CRREL hydrologic uses of LANDSAT imagery are being explored.

Data collection platforms tested by the Corps have performed successfully in all seasons, transmitting near real time operationally useful data for our flood fighting missions. The DCP's are useful and readily installed in remote or inaccessible areas.

The successful testing of the LANDSAT Data Collection System at the New England Division has encouraged serious consideration of the institution of an operational satellite data relay system on a Corps-wide basis. System analysis is being performed to refine cost data and to articulate the data collection needs of Corps users.